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THE PRE-MOENKOPI (PRE-PERMIAN?) UNCONFORMITY OF THE COLORADO PLATEAU

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There is a growing appreciation of the importance of the unconformity below the "Red Bed" series of the Colorado Plateau Province, as witnessed by the recent paper of Lee[1] on the subject. During a reconnaissance in southeastern Utah, northeastern Arizona, and northwestern New Mexico, the writer had an opportunity to gather some additional data on the extent and possible magnitude of the stratigraphic break, and these facts are herewith presented.

The first part of the paper deals with the local evidences of the unconformity at several points, particularly at Mule Twist Canyon, Utah; at Fruita, Utah; in Quartzite Canyon, near Fort Defiance, Arizona; at Ramah, New Mexico, on the Zuni Uplift; and near Tolchico, Arizona, on the Little Colorado River. The location of all these points is indicated on the accompanying sketch map (Fig. 1).

The second part of the paper begins with a summary of the known areal extent of the unconformity, and this is followed by a discussion of the magnitude of the stratigraphic break.

Since the formation names are largely local and probably unfamiliar to most readers, the following partial columnar section is given.

Jurassic,	La Plata sandstone
Triassic,	Dolores (Chinle) formation
	Shinarump conglomerate
Permian (?),	DeChelly sandstone (local)
	Moenkopi red beds

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[1] W. T. Lee, "General Stratigraphic Break between Pennsylvanian and Permian in Western America," *Bull. Geol. Soc. Am.*, Vol. XXVIII (1917), pp. 169–70.

Carboniferous,	Kaibab limestone	Upper Aubrey group, Pennsylvanian
	Coconino sandstone	
	Supai formation	
	Redwall limestone, Pennslvanian and Mississippian	

DETAILED OCCURRENCES OF THE UNCONFORMITY

Mule Twist Canyon.—The first locality at which the unconformity was noted is about four miles northwest of Mule Twist Canyon, a well-known pass through the La Plata "reef" or "ledge," a prominent escarpment on the east flank of the Water Pocket Flexure, west of Henry Mountains, Utah (Fig. 1). At this point the unconformity is distinctly indicated by basal conglomerates, by the uneven surface on which the Moenkopi rests, and by the

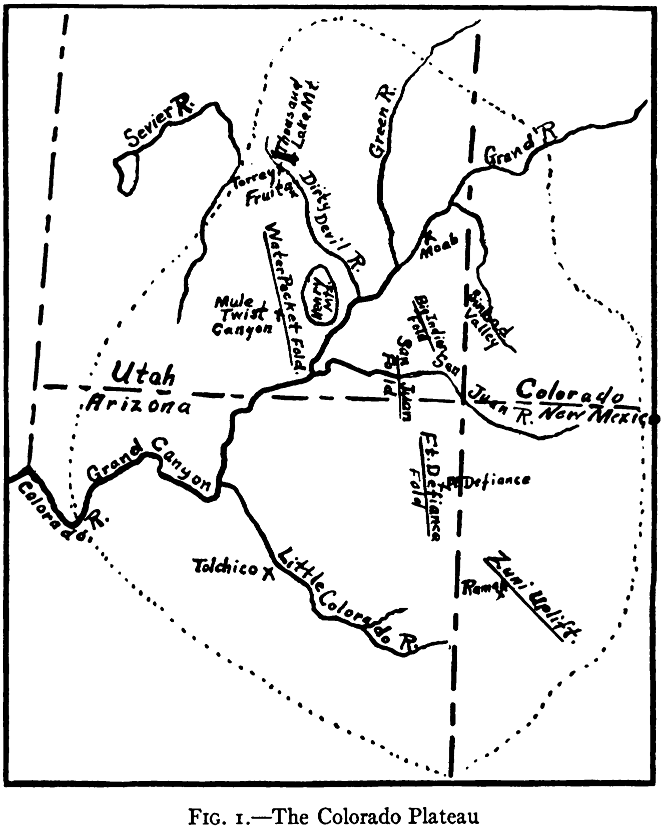

FIG. 1.—The Colorado Plateau

variable thickness of the Moenkopi itself. The following detailed section was measured in this vicinity:

SECTION NEAR MULE TWIST CANYON

(4)	100 feet	red and yellowish-gray sandy shale and some sandstone
(3)	60 feet	well-bedded gray fossiliferous limestone
(2)	40 feet	regularly bedded calcareous sandstone
(1)	75 feet	massive cross-bedded gray sandstone, base not exposed

The gray standstone and limestone are undoubtedly the Aubrey group of the Carboniferous mentioned by Gilbert[1] in the Henry Mountains. The limestones and upper bedded sandstones (members 2 and 3) were sparingly fossiliferous, and several species were collected, but the collection was unfortunately lost by the burning of an office building in which the writer was temporarily quartered. The fauna was totally unfamiliar to the writer, and consisted of very small crinoid stems, several pelecypods, and one or two small brachiopods. They did not resemble at all the faunas so abundant in the Goodridge formation of the San Juan Oil Field, a formation

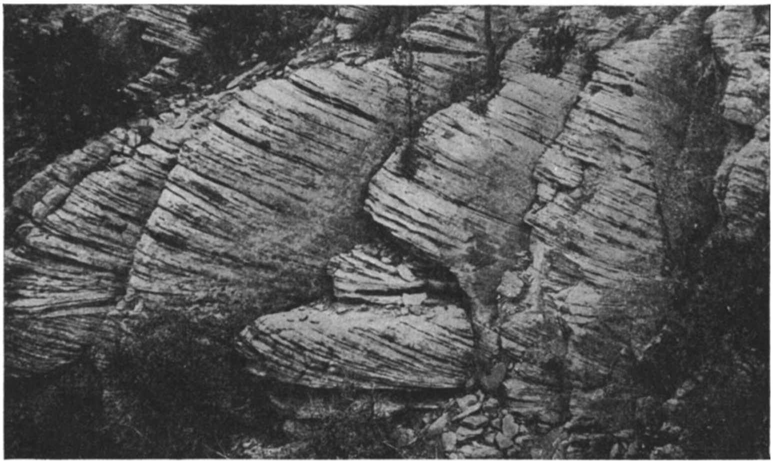

FIG. 2.—Cross-bedded Coconino(?) sandstone near Mule Twist Canyon, Water Pocket Flexure, near Henry Mountains, Utah.

[1] G. K. Gilbert, *The Geology of the Henry Mountains*, 1880.

provisionally correlated with the Redwall limestone. The cross-bedded sandstone (member 1) resembles very closely the Coconino. (Cf. Figs. 2 and 3 of this paper with Plates XXIX A and B, *U.S. Geol. Surv., Bull. 613*, which illustrate the Coconino in Walnut Canyon, Arizona.) The red and yellowish-gray sandy shales of number four rest on the slightly eroded surface of the limestone (member 3) with a very sparing development of conglomerate at the contact. The shales are gray at the base, but grade upward irregularly into the typical red sandy shales of the Moenkopi, which are in turn overlain, again with unconformity (Fig. 4), by the coarse sandstone and conglomerate of the Shinarump (restricted), and this is followed by typical Dolores and La Plata.

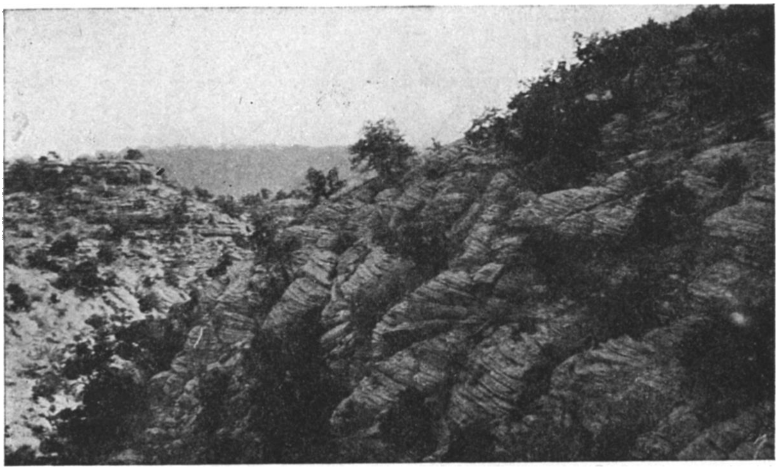

FIG. 3.—Cross-bedding in Coconino(?) sandstone, same locality as Fig. 2. Photo by Zoller.

At this point the unconformity is not very pronounced. About two miles northwest, however, near the south end of Wagon Box Mesa, a large mesa capped with Shinarump, the deeper valleys show red shale grading down through gray sandy shale into coarse sandy conglomerate. The conglomerate consists of pebbles of chert and limestone in a sand matrix, and rests directly on gray, cross-bedded sandstone. At this point the limestone seems to have been removed by the pre-Moenkopi erosion. Here, at the south end of the Wagon

Box Mesa, the Moenkopi is about four hundred to five hundred feet thick. Two miles north of the north end of the mesa, perhaps four miles from the last point described, occur some smaller mesas, also capped with Shinarump. Here the Moenkopi is not over two hundred feet thick. The change may in part be due to the post-Moenkopi, pre-Shinarump erosion, but is more probably owing to the uneven surface of the Aubrey beds, on which the Moenkopi was laid down. This seems the more probable, since at this point the Moenkopi is again noted to rest on the limestone member. In this vicinity the upper ledge of the limestone is itself distinctly conglomeratic.

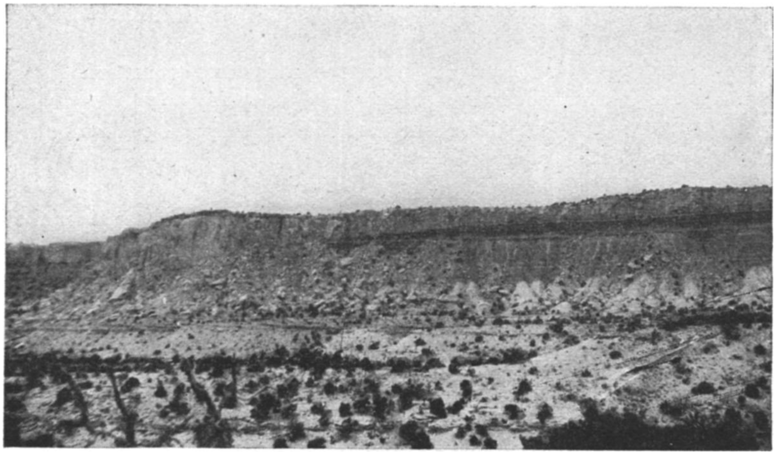

FIG. 4.—Unconformity of Shinarump conglomerate on Moenkopi beds, west of Wagon Box Mesa, Water Pocket Flexure, Utah.

The foregoing facts indicate a decided erosion of the Aubrey before the Moenkopi was deposited, an erosion amounting in places to probably two hundred feet or more, with the complete removal, at certain points, of the limestone beds, allowing the shales to rest directly on the cross-bedded sandstone member.

Fruita.—At Fruita, about forty miles northwest of the Mule Twist locality, the canyon of the Dirty Devil (Fremont) River cuts deeply into gray limestones and sandstones below the "Red

Beds." A rather detailed section was measured along this canyon, and the section is given below.

SECTION IN DIRTY DEVIL CANYON, NEAR FRUITA

26	50+feet	red shale, Moenkopi, slightly irregular contact, with a few pebbles
25	50 feet	limestone in massive ledge
24	55 feet	red shale
23	10 feet	covered slope
22	60 feet	limestone, chalky at base, sandy in middle, cherty at top
21	12 feet	covered slope
20	40 feet	white chalky limestone, with chert concretions
19	20 feet	covered
18	20 feet	gray limestone, weathers with a powdery surface
17	20 feet	covered
16	2 feet	chert
15	170 feet	non-bedded sandstone, very coarse at base, finer above
14	30 feet	sandy limestone, with quartzite ledges
13	13 feet	yellowish, very cross-bedded sandstone
12	4 feet	sandy gray limestone
11	12 feet	cross-bedded coarse white sandstone
10	15 feet	sandy gray limestone
9	10 feet	coarse gray sandstone
8	18 feet	thin-bedded argillaceous limestone
7	122 feet	cross-bedded coarse white sandstone
6	125 feet	cross-bedded white sandstone with some thin shale lenses
5	2 feet	thin-bedded shaly sandstone
4	45 feet	cross-bedded white sandstone
3	2–6 inches	greenish-gray shale
2	40 feet	massive cross-bedded coarse white sandstone
1	12 feet	covered slope above river

957 feet, all of which, except number 26, are Aubrey.

There is nothing in the section above that can be correlated with any great certainty with the individual beds in the vicinity of Mule Twist Canyon. Member number 15 may possibly represent the sandstones of the Mule Twist region, though this is uncertain. If it does, there are many more beds between it and the Moenkopi here than in the former section. The unconformity itself is not particularly well marked in the vicinity of Fruita, but the entirely different character of the beds on which the Moenkopi rests here and near Mule Twist constitutes a difference which perhaps might result from lateral variation, but which more probably indicates a different horizon as the base on which the Moenkopi beds were deposited. No fossils were seen in the Fruita section.

About ten miles northwest of Fruita, and perhaps three miles southeast of Torrey, the following section was measured across the contact:

SECTION NEAR TORREY, UTAH

16	... feet	red sandy shale
15	15 feet	gray shale
14	75 feet	red sandy shale
13	20 feet	gray to brown, thin-bedded sandstone
12	35 feet	red sandy shale, ripple-marked
11	15 feet	covered slope
10	14 feet	thin-bedded sandy gray limestone, upper contact concealed
9	2 feet	very crystalline, pitted gray limestone
8	16 feet	thin-bedded argillaceous limestone
7	5 feet	covered
6	15 feet	crystalline gray pitted limestone
5	3 feet	argillaceous white sandstone
4	3 feet	gray crystalline limestone
3	3 feet	fine-grained argillaceous white sandstone
2	52 feet	massive gray limestone
1	42+feet	red shale with gypsum veins, base not exposed

The boundary of the Pennsylvanian and the Moenkopi is here believed to occur between members 10 and 11. The red shale (number 1) of this section, below the fifty-two-foot ledge of gray limestone, is believed to correspond to the fifty-five feet of red shale (number 24) in the Fruita section, also below fifty feet of massive limestone. Beds 3 to 10 of the Torrey section seem to have been eroded off at Fruita.

Ramah.—On the west flank of the Zuni Uplift, about six miles east of Ramah, New Mexico, along a sharp canyon, followed by the main wagon road, the situation is as follows: about fifty feet of red sandy shales and sandstones rest with very uneven contact on gray massive limestones, of which perhaps fifty to one hundred feet are exposed. No fossils were noted, but it is confidently believed that the gray limestone is Aubrey and the red sandy shales and sandstones Moenkopi. The marked uneven character of the contact leaves no room for doubt as to the unconformable relation between them.

Above the Moenkopi is a thin conglomeratic sandstone taken to be the Shinarump, since above it rest characteristic ashy gray and purple shales highly suggestive of the typical Chinle (Dolores), so widely exposed in the De Chelly (Fort Defiance) Uplift.[1] The exceptional thinness of the Moenkopi here (50 to 100 feet) may be due in part to post-Aubrey and pre-Moenkopi erosion, in part to post-Moenkopi and pre-Shinarump erosion, and possibly in part to lack of deposition. No information was secured which would enable one to decide which of these might be the most important factor.

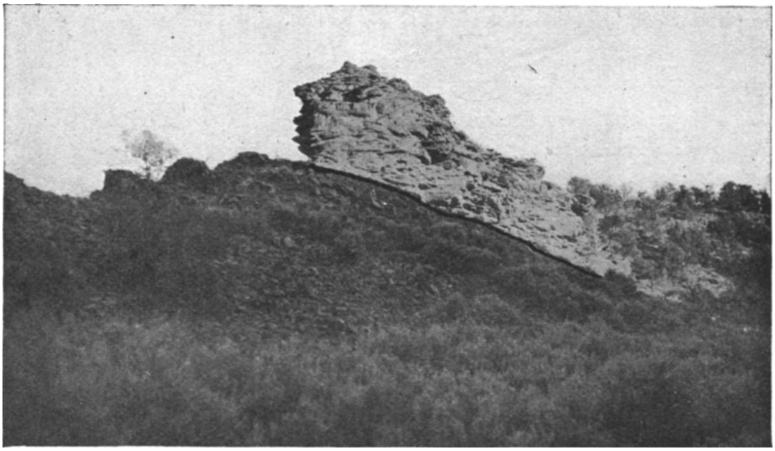

FIG. 5.—Nearly flat-lying Moenkopi unconformable on folded pre-Cambrian, Quartzite Canyon, near Fort Defiance, Arizona.

Fort Defiance.—In Quartzite Canyon, near Fort Defiance, Arizona, the Moenkopi rests directly on steeply dipping, much jointed, vitreous quartzite (Figs. 5 and 6). This relation has already been described by Gregory,[1] who says of it: "If strata of Pennsylvanian age once covered the quartzite the pre-Moenkopi erosion interval, elsewhere poorly marked, becomes here a stratigraphic feature of great significance. In my opinion the quartzite is a monadnock of a pre-Cambrian erosion surface—an elevated mass which outlived its contemporaries through Cambrian, Silurian, Devonian, and early Carboniferous time, only to be itself buried by the streams of Permian time." It would appear from this statement that Gregory does not incline to believe that the quartzite-Moenkopi unconformity is related to the Pennsylvanian-Permian erosion interval, but represents earlier unconformity with overlap. Here also it is not possible to determine the facts.

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[1] H. E. Gregory, "Geology of the Navajo Country," *U.S. Geol. Surv., Prof. Paper 93*, 1917.

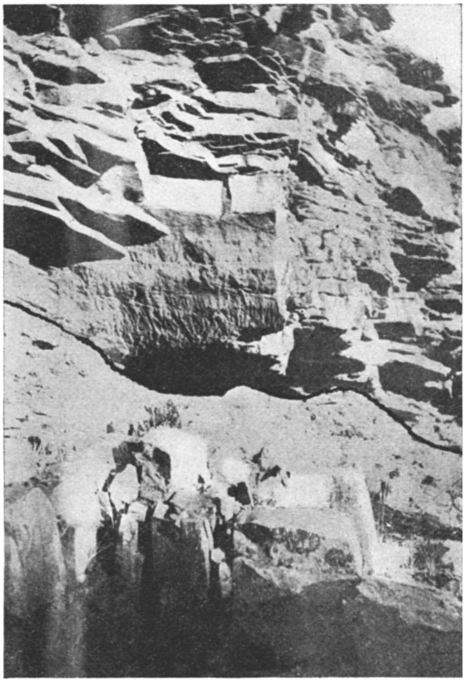

FIG. 6.—Same unconformity as in Fig. 5

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[1] H. E. Gregory, *loc. cit.*

Tolchico.—Gregory[1] sums up briefly evidence presented by several writers, pointing to unconformity at the base of the Moenkopi, which seems to be especially marked along the Little Colorado. The writer has seen the area described by Gregory near Tolchico, and while there is clear evidence both of pre-Moenkopi erosion channels and basal Moenkopi conglomerate, neither the eroded contact nor the conglomerate are as well developed here as near Mule Twist Canyon, west of Henry Mountains, unless the conditions described below are related to pre-Moenkopi erosion.

At a sharp bend in the Little Colorado River, perhaps two or three miles northwest of Tolchico, a deep sharp canyon is cut in the Kaibab limestone, and a sharply cut tributary canyon enters at the bend, from the southwest. Perhaps a quarter of a mile up the tributary canyon from its mouth occur conditions of peculiar interest. Within the canyon, which here cuts between seventy-five and one hundred feet into the Kaibab, and resting against the Kaibab walls with distinct and coarse basal conglomerate, are very friable, intricately cross-bedded, rather coarse sandstones. In color they are dark red, deep brown, and in places almost black, in which respect they contrast strongly with the gray limestone walls of the canyon between which they lie, and also with the cream-colored, white, or gray drifts of dune sand which surround them, in turn, and partly bury them. Their age was not determined, since they appear to be absolutely unfossiliferous. At first the writer inclined to the idea that they were a phase of the basal Moenkopi, resting in an old pre-Permian channel, and while he still admits the possibility of this interpretation, it is also considered possible and perhaps probable that they are a wind-blown deposit of Tertiary or early Quaternary age, consisting largely of materials derived from the Moenkopi. That they rest in a channel cut at least one hundred feet into the Kaibab limestone, that they contain a coarse basal conglomerate of limestone bowlders, and that they are distinctly older than the present dune sands, admit of no question whatever. The general character and relations of these deposits can be studied more clearly from the illustrations given (Figs. 7 and 8).

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[1] H. E. Gregory, *op. cit.*, p. 21.

AREAL EXTENT OF THE UNCONFORMITY

Many other workers who have studied the stratigraphy of this region have recognized the prevailing unconformity at the base of the Moenkopi, but in general it has heretofore been considered a minor break. The evidence goes to show that it is recognized over an area from the Little Colorado River in Arizona, east to the Zuni Uplift in New Mexico, and northwest to the Dirty Devil (Fremont) River in Utah.

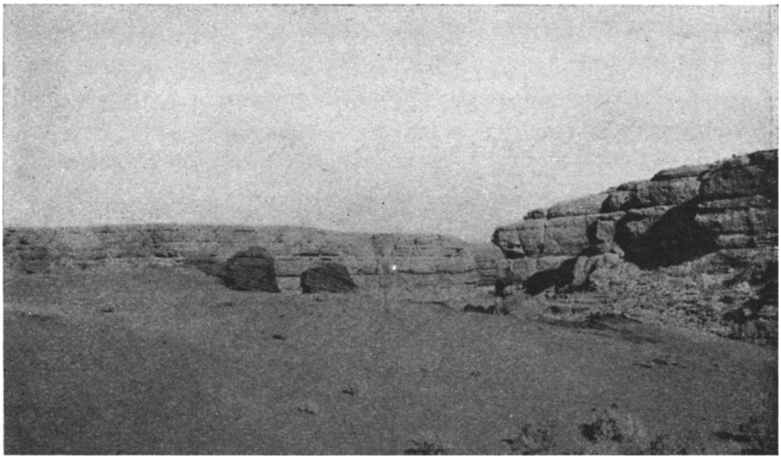

FIG. 7.—Cross-bedded sandy shale (the two dark masses to the left of the center) resting in erosion channel in Kaibab limestone; dune sand in the foreground. On Little Colorado River, near Tolchico, Arizona.

In the San Juan Oil Field, which lies about midway between the Ramah and Fruita localities, the Moenkopi, according to Woodruff,[1] rests on the Goodridge (Redwall?) limestone with "a sharp lithologic break," though he does not mention an actual erosion interval. Of the same place Gregory[2] says: "No undisputed evidence of unconformable relations between the Pennsylvanian and Permian (?) was obtained at this locality." He indicates, however, evidence of a probable break of importance in sedimentation. In view of the unconformable relations both northwest and southeast, it is highly probable that the unconformity also exists along the San Juan.

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[1] E. G. Woodruff, "Geology of the San Juan Oil Field, Utah," *U.S. Geol. Surv., Bull. 471*, p. 87.

[2] H. E. Gregory, *op. cit.*, p. 21.

STRATIGRAPHIC MAGNITUDE OF THE UNCONFORMITY

Stratigraphically, near Mule Twist Canyon, this unconformity represents at least two hundred feet of erosion. If the beds in the Mule Twist vicinity are actually different geological horizons from those near Fruita, rather than different facies of the same horizon, a conclusion that seems highly probable, then the pre-Moenkopi erosion was even greater.

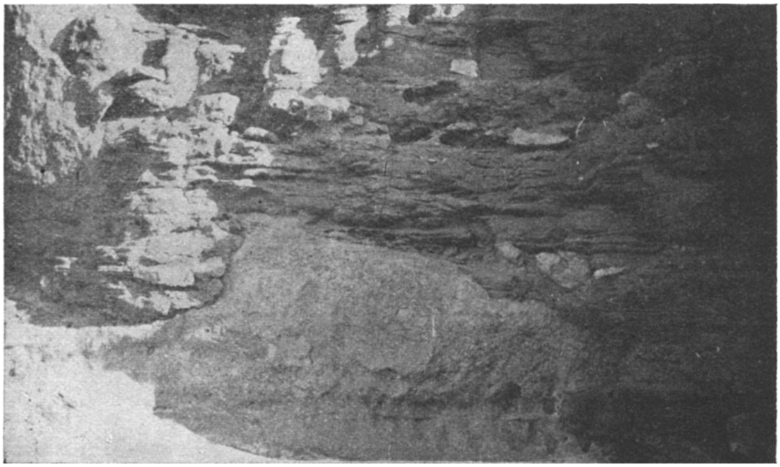

FIG. 8.—Detail of contact of sandy shale shown in Fig. 7, on Kaibab limestone. Note pebbles of limestone in the shale.

Let us examine now the significance of certain tentative correlations made by Girty and presented by Woodruff.[1] Regarding the age of the Goodridge limestone in the San Juan Field, Girty says:

> I have already examined and reported upon a collection from the Honaker trail, where a good portion of Mr. Woodruff's material was obtained. This collection was made by Robert Forrester, of Salt Lake City, Utah. Mr. Forrester, who has done much work of a very accurate kind involving the Mesozoic

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[1] E. G. Woodruff, *op. cit.*, pp. 75–104.

> and late Paleozoic rocks of Utah, reports that his fossils came from what was called Lower Aubrey group in the reports of the Wheeler Survey, their Upper Aubrey being our Kaibab limestone. The lists of fossils given by Meek as representing the fauna of the upper Redwall limestone show the same general facies as Mr. Woodruff's collection. The typical Redwall we know to be of Pennsylvanian age in the upper part and Mississippian age in the lower part, so that the facts at hand seem to indicate that the strata involved in Mr. Woodruff's collection represent the upper part of the typical Redwall limestone. I do not regard it as certain, however, that the marked dissimilarity of the Kaibab fauna to anything which Mr. Woodruff found in his section may not be regional and that by gradual modification some of his faunas may not pass into the Kaibab fauna at the same geologic level.

If Girty is right in his tentative suggestion that the Goodridge is the equivalent of the Redwall, the pre-Moenkopi erosion interval at once assumes greatly added significance as a stratigraphic break of notable magnitude, for this would indicate the removal, or non-deposition, in the San Juan Field of the Supai sandstones and shales, the Coconino sandstone, and the Kaibab limestone, all of which occur above the Redwall in the Grand Canyon section, the combined thicknesses of which are not far from two thousand feet. This supposition is perhaps somewhat strengthened by the facts observed near Mule Twist, where the formations resemble closely the Kaibab and Coconino. The fossils collected by the writer, had they not been lost, might have settled this point. It is to be hoped that other collections may be secured soon from that locality. From this it would seem that the Moenkopi may be resting on Kaibab limestone near Tolchico and in the Grand Canyon, on Redwall limestone in the San Juan Oil Field, and again on Kaibab limestone and Coconino sandstone near Mule Twist Canyon.

The foregoing is a possibility which, the writer finds, has already been considered by Cross[1] in explaining the fact that the Pennsylvanian directly beneath the "Red Beds" at Moab carries a different and possibly older fauna than was found by Powell and Newberry below the Red Beds farther west on Colorado River. Cross says:

> There may be a stratigraphic break, due to uplift and erosion, through which the Aubrey strata found by Powell and Newberry have been removed at Moab, in the Sinbad Valley, and to the mountain region to the east. This

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[1] Whitman Cross, "Stratigraphic Results of a Reconnaissance in Western Colorado and Eastern Utah," *Jour. Geol.*, XV (1907), pp. 634–79.

implies that the Hermosa beds of Moab are present beneath the section examined by Powell and Newberry. Such a break must occur at the base of the Paleozoic "Red Beds," and no suggestion of such a hiatus has come from observations in Colorado; but it is to be remembered in this connection that in southern Utah and northern Arizona, Powell, Gilbert, Dutton, Walcott, and others have noted a persistent unconformity by erosion between the Aubrey and the succeeding strata now commonly referred to the Permian through Walcott's discovery of fossils in the Kanab Valley. All of the above-named geologists have observed a conglomerate more or less widely distributed at the base of the Permian series, composed in large part of pebbles derived from the Aubrey rocks, as shown by fossils contained in them. It is, of course, possible that the denudation at this horizon may have been much more extensive than the observations thus far reported would suggest.

The direction even of this change corresponds to the facts observed by the writer. According to the statement by Cross, the beds on which the Moenkopi rests are younger to the west, older to the east. Similarly the writer finds that in the San Juan Oil Field, about in the longitude of Moab, the Moenkopi rests on beds which are possibly as old as Redwall, while farther west, at Tolchico and at Mule Twist Canyon, the Moenkopi seems to be resting on younger beds, probably the Kaibab.

That the beds below the Moenkopi near Mule Twist Canyon were equivalent to the Kaibab and Coconino, and were not equivalent to the Goodridge, was the independent conclusion reached by the writer, even before he was aware of the foregoing statements by Girty and by Cross. In view of the uncertain condition of this correlation, it was felt that these few notes might add to the general knowledge regarding the extent and magnitude of this break.